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A LEADER, OR JUST A MANAGER? SEVEN TRAITS MAKE THE DIFFERENCE

BALANCING YOUR WORK AND HOME LIFE— A CRUEL TUG OF WAR

AUGUST 16, 1985 VOL. 228, NO. 16 ·

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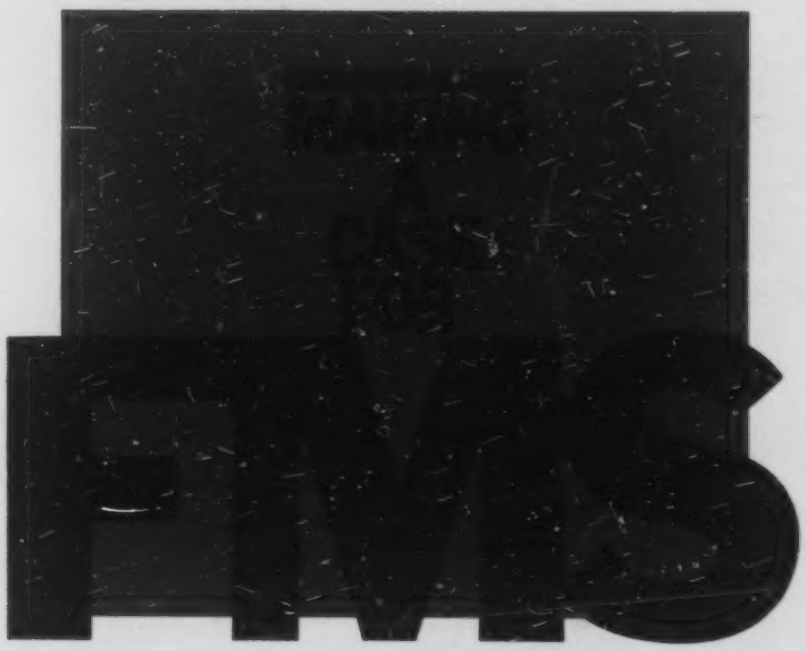

Editorial 7
Hey, Julie! Wait for me!

Newswatch 13
Specialty steelmakers ask Congress to keep a close watch on imports.

Financial Analysis 25
How to save a failing company.

You And Your Job 29
Workers can survive a takeover.

Flexible Manufacturing Systems 31
An in-depth look at the top systems around the world.

Leader or Manager 58
Seven key traits distinguish the best and the brightest.

Tug Of War 63
Many managers are caught on a tightrope between work and home.

Materials Report 71
Steel producers are pursuing joint ventures to avoid overexpansion.

Order Trends 76
It's still all quiet on the price front.

Next issue: Iron Age's 250 fast growth companies.

Departments

EDITORIAL STAFF	8
SIGNED, SEALED AND DELIVERED	8
INDUSTRIAL BRIEFS	18
AD INDEX	66
BUSINESS STAFF	66
MANAGEMENT SERVICE CARD	67
PRODUCT & EQUIPMENT REVIEW	69
P&P DATA 7/22	72
FERROUS SCRAP 7/22	73
CLEARING HOUSE	74

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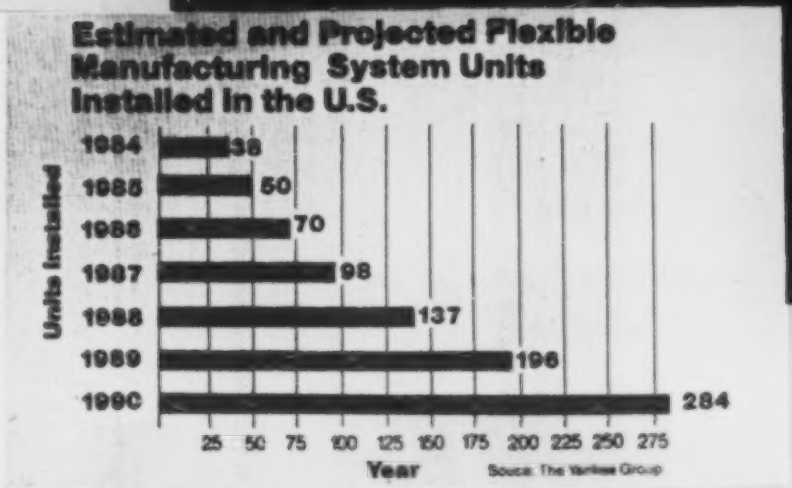
MAKING A CASE FOR FMS

Most flexible manufacturing systems of the past were not very flexible at all, but computers and software are now changing industry's view.

BY ROBERT E. HARVEY AND JAMES B. POND



Fads—in manufacturing circles as elsewhere—come and go. Several years ago discussing flexible manufacturing systems (FMS) was the rage, but with arrival of new buzz words like computer-integrated manufacturing (CIM) and artificial intelligence (AI), FMS fell out of fashion. Funny thing though. In the past year or two, never before have more flexible manufacturing been purchased, never has their future looked so bright.

In 1982 some 14 U.S. systems were in operation. That number, according to the Yankee Group, a Boston consulting firm, rose to 38 in 1984, will top 50 by 1985, and 300 by 1990! These systems represent the cream of world manufacturing systems. They are worth examining if only because they represent technology's leading edge. However, if flexible manufacturing is viewed as the culmination of a long journey that begins with numerically controlled machine tools, progresses through flexible machine cells (FMC) and ends in FMS; then FMS, for many firms, is the future and therefore worth a look.

A few of these state-of-the-art flexible systems are reviewed over the next few pages. Primarily because of their use of more powerful computers and more sophisticated software, they are substantially more advanced than earlier systems.

However, new FMS developments are just over the horizon. Tomorrow's systems will rely increasingly on software with artificial intelligence capabilities that will permit a high degree of adaptive control. Adaptive control will permit reaction in real time to unexpected changes in the system. Future systems, using advanced sensing technologies like machine vision, will self-correct.

In addition, FMSs will become increasingly efficient. When faced with choices as to the best way to operate, tomorrow's systems will be able to simulate all possible options, then choose the optimum path—all in real time. By way of contrast, simulation packages today can take several hours to run.

Today, an FMS is an integrated system of machine tools and material handling equipment designed to manufacture a variety of parts at low or medium volumes at relatively slow production speeds. Tomorrow's FMS will produce parts at much faster rates.

Although they have some characteristics in common, current FMSs are a diverse lot. A few systems, for example, are not very flexible and can only machine three or four different parts. Other systems, however, were designed to machine up to 500 parts. Most FMSs have at least four workstations but some have as many as 32. Some systems move parts from workstation to workstation by automated wire-guided vehicles while others use conveyors, monorails, carts on tracks and robots. And most current systems, but not all, were supplied by one vendor.

VOUGHT CORP.

In the past many FMS systems turned up to be more flexible in concept than in fact. Owners found that the systems were best employed turning out large numbers of a relatively few varieties of parts. Truly flexible manufacturing systems, such as Vought's FMS, are a very recent development.

The Vought installation currently handles 531 different parts, usually in batches of one. This super flexibility is primarily the result of advanced software.

"We saw the flexibility as the key to the long term utility of the system. But we recognized at the outset that there were some additional cost and risk associated with a system that gives you that flexibility," observed Art Roch, Director of Industrial Modernization, Vought Corp., Dallas, a subsidiary of LTV Corp. "I don't think that we have done anything mechanically that has not been done some place else. What we have done better than most, I believe, has been to implement a computer control system that does give us the ability to go to serial production."

In batch production, unlike serial production, large numbers of a particular part are produced and stored awaiting subsequent components.

At the facility, a complete set of parts for a given application can be made in sequence, greatly reducing materials inventory and storage requirements. Serialization is possible because the system takes parts in random order. So a single, one-of-a-type part can be processed without disrupting the production flow.

Serial production, it was decided, meant that multiple parts per pallet were necessary. Now, up to 16 part numbers can reside on one pallet.

"Multiple parts on a pallet is one of the key features on the system in that it permits us a more efficient load/unload operation, but more importantly it increases our spindle utilization," explained Mr. Roch. "Essentially the approach we took with was that the spindle was the most precious resource we had. So all the software and all the queuing and material handling is geared to maximize spindle utilization."

At Vought, the software—the computer control system—is the key. The firm uses the computer to schedule all of the activities within the system—everything from cutter management to actual movement of jobs and downloading of NC programs within the cell.

Software development was a joint effort between Vought and Cincinnati Milacron, the supplier of the system.

The $10 million system, or flexible machining cell, as the company calls it, includes eight machining centers with automatic tool changers and 90-tool magazines; an automated clean station; two automated inspection stations; two 10-pallet carrousels for parts pickup and delivery; and four robot carriers.

The FMS is but one of several planned by the firm. A high-speed system that handles parts within an envelop of 180 in., by 60 in., by 24 in. has a 1988 completion date.

Another FMS for the fabrication of composites also is planned.

Despite its extreme versatility, Mr. Roch calls Vought's current FMS a first generation system. The later, second generation ones will have more computer power, improved software, and faster hardware. They will have, for example, the ability to run simulations of possible courses, the intelligence to select the optimum course, and the speed to do it in real time.

An FMS at Vought meant a great deal of change. To handle that change, management, one year before the cell was operational, named a cell manager. He began assembling the people we wanted to help him run the cell and establish the procedures he wanted to utilize.

"This manager was the first person involved from the operations side of the house," pointed out Mr. Roch. "It is very important to get operations people involved early on."

The $10 million flexible machining cell includes eight machining centers with automatic tool changers and 90-tool magazines; an automated clean station; two automated inspection stations; two 10-pallet carrousels for parts pickup and delivery; and four robot carriers.

INGERSOLL MILLING MACHINE

This $20 million FMS, consisting of 12 machines, will replace 40 stand-alone machines and be able to process 25,000 different part types annually with 70 pct of the parts produced in lots of one.

When it rains it pours. Ingersoll Milling Machine Company, Rockford, Ill., besides being in the midst of building several FMSs for customers, including a system going to General Motors, is installing a system in its own facility. To better handle this FMS deluge, the company has formed an Integrated Manufacturing Systems (IMS) Group, strengthening and focusing Ingersoll's commitment to FMS.

The FMS that Ingersoll is building for GM's Buick-Oldsmobile-Cadillac Group is composed of seven Ingersoll/Bohle 30 hp 4-axis CNC horizontal machining centers. It is going to Grand Blanc, Mich., and will be called upon to randomly produce over 250,000 parts per year. Primarily welding jigs and checking fixtures, in lot sizes as small as one, will be produced.

Despite its spate of FMS orders, Ingersoll is keeping one system in-house. When completed, this $20 million FMS, consisting of 12 machines, will replace 40 stand-alone machines and be able to process 25,000 different part types annually with 70 pct of the parts produced in lots of one. Six machining centers are already in place and operating. The balance of the $20 million installation will be phased in by the end of 1986 without interrupting interim manufacturing schedules.

The goal is for the third shift to run unattended. And when this goal is reached, "there will be approximately 75 pct fewer operators than now required," commented a company spokesman. "However, this saving is incidental to the reduction in overhead costs that will be realized. Primary objectives of the installation are uninterrupted work flow, reduced inventories of work-in-process, reallocate floor space and less manufacturing-support manhours."

As part of Ingersoll's light machine shop, the automated system will process workpieces the size of a 40-in. cube or less in the small lot sizes peculiar to the company's special machinery business.

When compared to other FMS, the Ingersoll system may well be the most flexible because most of products the firm produces are one of a kind. This means that the large majority of parts produced on the FMS will be made in lot sizes of one, and maybe 50 pct of these parts will never be made again.

The system employs centralized high rise parts storage and automatic guided vehicles that will transport palletized work to and from automatic pallet changers at each machine tool.

Tool management will include tool monitoring according to normal life cycles and current condition, with automated replacement or worn and broken tools. Other features include an automated parts cleaning area and inspection of finished work by coordinate measuring machines.

"All of the components of the system, the machines, the carts, the tool set-up and transportation system, and the storage system all communicate with each other. When a warning or emergency situation occurs, the system will try to correct itself, such as with tool compensation," explained George J. Hess, vice president of systems and planning. "If it is unable to, it will signal a fault condition through the monitoring system to alert the operator. The system is being designed to be as nearly automatic as possible, and the software is designed so that it is flexible and very adaptable to change."

According to Mr. Hess, an important motivation behind installation of the FMS was to improve product quality by gaining a new level of control over some the most critical processes in the manufacture of its products. The company, however, is able to exercise this high level of control because the system also will allow Ingersoll to reduce costs and increase production.

Along with its extreme flexibility, what really diferentiates Ingersoll's FMS from other systems is that it is an integral part of a much larger integrated corporate business system. "The FMS is just the latest part of the computer integrated manufacturing system to be fully automated," continued Mr. Hess. "This is why we now call our overall system the computer integrated flexible manufacturing (CIFM) system."

GENERAL ELECTRIC-ERIE

The system, which was designed and built by Giddings & Lewis, Fond du Lac, Wis., has nine heavy-duty machine tools—two vertical milling machines, three horizontal machining centers, three heavy horizontal boring mills and one medium horizontal mill.

General Electric's motor frame FMS at its Locomotive Works in Erie, Pa., was the first flexible random machining system within the company. Though it captured about 100 pct of the publicity of GE's extensive modernization program at the aging Erie facility, the FMS area represents less than 1 pct of the total locomotive works.

The system, which was designed and built by Giddings & Lewis, Fond du Lac, Wis., has nine heavy-duty machine tools—two vertical milling machines, three horizontal machining centers, three heavy horizontal boring mills and one medium horizontal mill.

The machines are tied together by a 212 foot-long rail-tracked, chain-driven transporter which moves frames between 21 load/unload stations in the system.

All of these machines are equipped with GE 1050 CNC controls, while the transporter is controlled by a GE Series Six Model 6000 programmable controller, which in turn is interfaced into an executive DEC PDP 11/14 computer which directs and trends the activity of all system elements, with redundancy by a sister computer.

The computer, acting on production requirements entered by the system manager or the computerized material requirements system, displays to load/unload personnel at the fixture set-up station the sequence of parts to be loaded in order to maximize system productivity. After each frame is loaded in its fixture, and the computer signals it is ready, the computer selects the work station that can perform the first machining operations and will be available in the shortest time.

Each part continues through the system, always dispatched to the next available machine. It twice returns to the fixture set-up station to be refixtured for two other attitudes. An average of eight machining operations are required.

Over 500 cutting tools are stored within the nine machines. Each machine has either robot tool changing or storage for all the cutting tools required for the parts family, including backup tools, to keep the system operating for a full day. An automatic chip removal and coolant recirculating system is employed.

According to GE officials, it was originally planned to machine a family of six motor frames averaging 30 in. x 30 in. x 45 in., and weighing up to 2,500 lbs.

Capacity envelope of the system is 4 ft x 4 ft x 5 ft. An additional family of four motor frames and gear boxes weighing as little as 150 lbs was added later.

The motor frame is a fabrication containing both formed and cast elements. The typical frame has more than 140 machined surfaces on all six inside and six outside surfaces.

Many of these surfaces have tolerances of 0.001—0.003 in. Surface finishes are in the 125—250 microinch range.

The load station is custom-designed to assure even stock distribution. It uses hydraulically powered, self-centering arms which register on the inner surfaces of the fabrication. After the part is centered it is clamped in the fixture and transported as an integral unit.

The executive computer, acting as the brains of the FMS, directs each frame and gear box through the system. If a machine is down for repairs or maintenance, it is automatically isolated from the system and production is rescheduled using the remaining stations.

Production capacity of the flexible manufacturing system is over 5,500 frames annually.

The cost of the FMS was said to be $16 million. The benefits of this investment include a 240 pct overall employee productivity improvement, improved part quality and consistency, a reduction in cycle time from 16 days to 16 hours, and a 38 pct increased capacity in 25 pct less space with expandability to 100 pct increased capacity within the same space.

COMAU

From the beginning, FMSs going into U.S. plants were installed by U.S. companies. Because of the specialized nature of FMSs, many thought this practice would continue indefinitely. However, there has been a rude awakening. Flexible manufacturing systems from overseas are beginning to find their way into U.S. plants.

Boeing Aircraft's Seattle plant, for example, has an FMS engineered by Shin Nippon Koki Co. Ltd., Osaka, Japan. It contains five SNK five-axis machining centers, a coordinate measurement machine, two wire-guided vehicles, an AS/RS and a VAX 11/30 computer.

Another system manufactured abroad has been installed at Borg-Warner Air Conditioning, Inc., York, Pa. The system, costing $9.6 million, was put in by Comau S.p.A from Torino, Italy. It was Comau's second FMS in America. Earlier, a smaller FMS went to Cheverolet.

Comau was selected by Borg-Warner over better known firms because of its software expertise, its reputation as a complete system designer, its past record of performance, and its promise to assemble and test the system prior to installation at the York plant.

The Borg-Warner FMS has a buffer which can hold eight production-hours' worth of parts to be machined. In the center of the buffer, a stacker automatically circulates parts to and from the FMS. Once on the conveyor system, the part moves to a lathe or one of four horizontal machining centers. The system combines turning, milling, and boring.

"Identically tooled, each machining center has as 140-tool capacity which covers all conceivable drilling and cutting operations required," explained one official. The 20-hp, variable speed machines have adaptive control and part spindle probes.

Other special features include through-the-tool coolant and part deburring tools. All parts are washed once. A robot washes the hard-to-get interiors of parts through their machined openings. The FMS is making a highly varied range of parts for compressors. The parts range from 5 lbs to 1800 lbs.

The master computer for the system is responsible for: operations control, planning, reporting, information system interface (IBM link), machine programming, in-process inspection, material handling and tools management.

Comau, the supplier of the system, does much more than just build machine tools or machining systems. "Comau is an Italian machine tool company (with over 3,500 employees in Italy alone) that specializes in large projects, especially involving specialty machines as opposed to standard machine tools," said Dr. Guy Lombardo, president, Comau Productivity Systems Inc., Troy, Mich. "Its product line is extremely diverse. It is the broadest of any company I know. It has welding equipment, robots, and material handling systems as well as metal cutting and mechanical assembly."

The company produces standard equipment but those standards are more the exception than the rule, and even the standard equipment is designed primarily to be modules within larger systems.

Besides building FMSs, Comau is busy with other projects. "We have two major projects with GM, one of those is for cylinder heads for engines and that involves two GM plants. We are doing metal cutting and automatic assembly there," said Dr. Lombardo. "The other project, the first of its kind in the U.S., is the automated guided vehicle-based body assembly of a car. We have the turnkey responsibility for that body assembly at two General Motors facilities."

Both systems involve no direct labor and both offer limited flexibility. "Let me give our philosophy about flexibility," continued Dr. Lombardo. "Flexibility involves a certain amount of judgment, because if you make something totally flexible, it costs you an arm and a leg. And it gives you a range of flexibility you never expect to use. If you want to keep costs under control, it is important to judge the range of flexibility that is appropriate to the problem." And FMS might not always be appropriate.

The Borg-Warner FMS has a buffer which can hold eight production-hours' worth of parts to be machined. In the center of the buffer, a stacker automatically circulates parts to and from the FMS.

HUGHES AIRCRAFT CO.

The Hughes' FMS features nine 15 hp MilwaukeeMatic 600 4-axis CNC machining centers. Each of the horizontal spindle machines can store up to 68 preset tools. The FMS includes automatic palletized inspection on a Cordax measuring machine.

Precision machining on a flexible manufacturing system is gaining widespread interest with increased demands for tighter tolerances and for lighter components.

At the Electro-Optical & Data Systems Group, Hughes Aircraft Co. in El Segundo, Calif., is an FMS supplied by Kearney & Trecker Corp. that is designed to handle and machine five different fragile aluminum housings for military equipment.

The housings are manually fixtured on 24 in. sq. pallets at a station located near the toolroom.

The housings typically have 400 machined surfaces, 165 being through holes, 119 tapped holes and 40 are milled surfaces. Inspection is required on 305 of these surfaces. Tolerances are typically ±0.002 in., while some call for ±0.001 in.

The Hughes' flexible manufacturing system features nine Kearney & Trecker 15 hp MilwaukeeMatic 600 4-axis computer numerically controlled machining centers. Each of the horizontal spindle machines can store up to 68 preset tools. The FMS includes automatic palletized inspection on a Cordax CMM.

Material handling uses a below-the-floor towline cart system, by S.I. Handling System, to allow random processing of the workpieces. This system is controlled by a DEC ll/44 central computer system that automatically delivers and removes workpieces to and from the machine tool modules and the inspection measuring machine. The inspection machine station randomly samples 20 pct of the workpieces.

Each of the machining centers is equipped with a spindle probe which is used to compensate for thermal drift.

One of the major differences of the Hughes FMS compared with comparable systems is a decision support system called Flexplan, developed by Charles Stark Draper Laboratories and Hughes Electro-Optical, that simulates and optimizes the operation of this FMS.

Henry R. Graf, Associate Manager, Fabrication, at Hughes, described the Flexplan as having six software modules that address problem areas inherent in the operation of a flexible fabrication system (FFS), as they call it. The advantage of this is that it is extremely difficult for the operator to foresee the consequences of many of the decisions that he may face without computer assistance. The results are shown graphically, which is a great time saver.

The executive software enables communication between the FFS and the computer-aided manufacturing center's HP 3000 computer. The executive software prompts the operator for data to define the problem and it then searches its data base and the Flexplan modules for information.

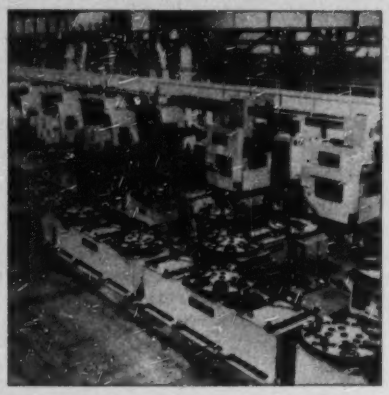
The end result is an indicated recommendation for the operator to follow, though the software may carry out the corrective action itself if it is possible.

According to Hughes, the predictive side of Flexplan includes a detailed simulation that mimics the major activities of the system and tracks the important measures of performance such as production and utilization. This is accomplished by a module that simulates the behavior of the FMS accurately to answer what-if questions asked by the operator. Hughes said that real time simulation will be a critical element in future computer integrated manufacturing systems.

One of the interesting aspects of the Hughes FMS is that all of the machining centers are not in full use all of the time. One or two are held in a standby condition so that normal scheduled maintenance can be carried out. In the long run, however, production apparently is more consistent with partial rather than full-time machine schedules.

On the other hand, each of the machining centers is virtually the same due to the use of CNC as part of the quality control program. The machine's spindle probe regrids the machine automatically when the machine drifts out of tolerance due to temperature. Periodically, the probe's accuracy is tested.

YAMAZAKI MACHINERY WORKS



Most of the machine tools used at the Minokamo plant are built by Yamazaki. Many are capable of unmanned operation so that a third-shift can run either partially manned or unmanned. During the normal day and second shift, the plant needs 240 employees. At night on the third shift, only ten.

The Minokamo factory of Yamazaki Machinery Works, Ltd., near Nagoya, is the company's third modern FMS facility and therefore incorporates the lessons learned by its predecessor FMS installations.

The flexible management and manufacturing system (FMMS) features 60 computer-controlled machine tools and 28 universal and special purpose machines. These machines are linked by 32 robots plus conveyors and carting systems.

Six computer systems are needed to control the entire system and the buildings in which it is housed.

Much to the chagrin of competitors, Yamazaki geared production for 120 machine tools per month but also intended to increase that level at some future time.

According to the company, it only takes one month to produce a lathe that formerly took three months. This shortened production time considerably simplifies projecting production with market needs.

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Yamazaki uses five main machining lines. One of these is a gearbox line that is operated around-the-clock seven days a week.

A flange line has eight CNC machine tools which include a Slant Turn 40N mill center lathe that is capable of drilling, tapping and milling operations in addition to turning; VQC-20/40 vertical machining centers, HQC-30 horizontal machining centers, and seven robots.

A spindle line has seven machine tools, including grinding machines and hardening equipment.

A box machining line includes twelve horizontal machining centers . Three robots are used to load/unload workpieces. Pallet storage capacity is 228 pallets and workpieces are linked to the rest of the system by robot carts. This line can machine unmanned for up to 48 hrs.

A frame cutting line uses seven CNC machines, including a YMS H25Q machining center that is capable of machining five faces of a workpiece. This line also has an NC bed grinding machine and hardening equipment. Three robots handle the workpieces and robot carts link the line with the system.

A large-frame machining line handles the largest machine beds, which weigh up to 25 tons. An extended YMS H50Q has a 15 meter X-axis stroke.

According to reports, there are 12 varieties of frames and the total production per month initially was 240 parts. The machining cycles on some of the frame lines last for as much as 12 hrs. Cutting tools are automatically fed to the machines by a special tool drum shuttle robot.

Assembly is also automated. Finished machined components arrive at the main assembly area by robot carts and to the unit assembly area, located on a second floor, by automatic elevator robot.

The entire machine shop is on one level while the computers, services and sub-assembly areas are located on three levels located at one end of the factory. The machine shop is environmentally controlled with a closely held temperature, in keeping with the ultra-precision machining requirements set by Yamazaki.

The line pictured shows the in-line arrangement favored by many Japanese builders. The robot cart servicing the machines is carrying a circular pallet loaded with eight workpieces. The pallets are stored along the line and are transferred to an indexing pallet station where a robot arm transfers the workpiece to the machine and the finished component to the pallet. The robot cart in the aisle removes the pallet containing finished-machined parts and transports them to the sub-assembly area.

LUCAS MACHINE

Lucas Machine is among the world's machine tool builders that have incorporated an FMS as part of its own in-house production system.

A $6 million dollar price tag for the FMS was announced; justified in part by the company's estimate that the new system would cut its production costs in half.

Basically, the FMS at the Lucas plant in Cleveland consists of two machining centers, a large coordinate measuring machine, an automatic guided vehicle (AGV), and a full tool management system. The total FMS system occupies about 12,000 sq. ft. of plant space.

The two machines are a Lucas Model 20MC machining center, that uses 800 mm sq. pallets, and a Model 30MC, that uses 36 x 48 in. pallets.

The machining centers are equipped with a GE 2000MC controller, with the entire system directed by a DEC VAX 11/750 computer.

The tool management system developed by Lucas has the capability of automatically recording tool length and diameter, identification of the tools by bar code and automatic transfer to and from the machining centers. The tool management system is also capable of tracking tool life and detecting broken tools.

Tooling is preset, using a digital presetter that is capable of setting tool lengths and diameters to 0.0005 in. and also provides automatic entry of tool offset data to the system.

One of the concepts employed by Lucas is the use of mobile tool storage in addition to tool storage in the tool changer drums at the individual machines. This makes unattended operation possible without resorting to excessively large tool changer drums.

Tools weighing up to 75 lbs each can be handled. A pick-and-place robot is used to insert and remove the tools from the tool changer storage drums.

The all-important chip management needed for unmanned machining includes chip purging at the work area as well as removing chips via the wire-guided transport vehicle that is normally used to transport fixtured workpieces to and from the machining center and tools to and from the tool preset area.

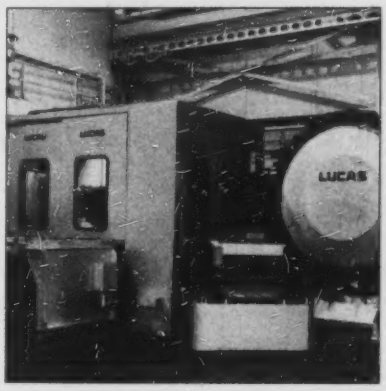
The automatic guided vehicle, which was manufactured by Litton/Automated Vehicle Systems, has a capacity of 6,000 lb. The company said that the wire guided path of this automated transport system can be easily expanded or changed, so it considers this to be the most flexible method to use for material handling.

The Lucas FMS produces prismatic parts requiring a wide variety of tools but the company points out that the real effectiveness of this system in based on the software it has developed to make the system work.

Lucas FMS software is modular and each highly structured module consists of submodules, which consist of sub-submodules, etc. The software makes use of multiple hierarchal structuring, which means that it can easily be expanded, modified or enhanced. One of the nice aspects of this system is that it is designed to be operated and supervised by shop floor- rather than computer-oriented people. The design of the software allows it to operate and function without complete and expensive restructuring to meet individual user requirements, the company states. Touch screen technology allows operators to obtain detailed information by merely touching the desired item on the screen's menu. Color screen graphics simplify the scene.

The use of animation is also helpful. Animation is used to show motion of tools and parts as handled by pallet shuttles, robots and transport vehicles. If things get confusing, Lucas has provided "Help" displays on the screen that give on-line instruction to the operator. This also minimizes the need for operator manuals, the company said.

The ability of the Lucas system to operate in an unattended mode is derived from the use of real-time simulation of system operation to provide scheduling of system resources. Thus, the company said, the system is capable of automatic rescheduling of parts processing.



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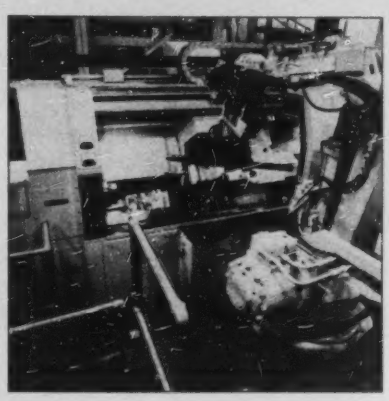
HARRIS GRAPHICS CORP.



The initial Harris SMS has nine CNC machines, with five different numerical controls; five machines that have Allen Bradley programmable controls; and four manually operated machines. Three Cincinnati Milacron T³ robots are used to load/unload machines. There are two manual stations.

Often alluded to but with too-few details publicized, the "FMS" at Harris Graphics Corp. in Fort Worth, Texas, is one of the pioneer systems in the U.S. involving turning operations. Those familiar with the system consider it a computer automated system and describe it as a structured manufacturing system (SMS) consisting of inter-related units using off-the-shelf general purpose machine tools.

Harris Graphics is the largest U.S. manufacturer of printing equipment which require a lot of rolls, shafts and cylinders. The installation was designed to produce five families of cylindrical parts having over 700 different part numbers. Some of the parts weigh 1,000 lbs.

The initial Harris SMS has nine CNC machines, with five different numerical controls; five machines that have Allen Bradley programmable controls; and four manually operated machines. Three Cincinnati Milacron T³ robots are used to load/unload machines. There are two manual stations.

The line is also unusual in that it contains two Landis cylindrical grinders with AB 7360 CNC controls and Heidenheim in-process gaging systems, and a Fortuna cylindrical grinder with an Elseta CNC and Heidenheim in-process gaging. The cylindrical grinders are tended by Milacron T³ robots.

The material handling system, which basically controls the SMS, includes wire-guided carts and is controlled by a programmable controller.

Raw material starts at in one end of the system by being cut-to-length (up to 24 in. long) on a Wagner cut-off saw under programmable control. A MTI inertial friction welding machine joins the shafts with the bearing shaft support. The assembled units go to two Pratt & Whitney Horizon Five machining centers for centering operations (one of the machines is on a slide to adjust for different lengths), and then to the robot-loaded CNC lathes, CNC grinding machines, etc.

The lathe cell consists of two Cincinnati Milacron 4-axis lathes that have opposed turrets.

One "manual ceil" has a Cincinnati Milacron 3-spindle CNC Hydratel for cutting multiple keyways into rolls, shafts and cylinders; a Gilman balancer; and a straightener. In another manual cell, Harris Graphics has a gun drilling machine and a planer.

Computers used to direct this system include a DEC PDP 11/44 with 32 bits per word, with a RSX-11M operating system. The cell manager on the shop floor is a DPM 50 (DEC PDP 11/23) with a RSX-11S operating system.

The Harris Graphics system was developed under the guidance of John A. Maddox. The software approach taken is *defined* as a distributed system from the top down, but was *designed, developed and implemented* from the bottom up. It is modular to allow for future expansion. The system is interactive. The managers said that software delays and problems do occur from time to time, so they go to manual operation until the problems are solved.

Mr. Maddox, who is now a consultant, cautions that if you cannot write software, you cannot have an FMS; you must be able to do it yourself, in-house, to retain control.

"The main point to remember in any major capital installation," Mr. Maddox said, "is that the hardware is only about ten pct of the problem. The more time spent defining and understanding your requirements, both short and long term, the greater are your chances of achieving a successful installation."

Mr. Maddox noted that batch type operations usually mean lower volumes but more variety.

He pointed out that flexibility of production requirements cannot be the sole responsibility of manufacturing operations management, but must be shared by every facet and managerial discipline with a manufacturing facility. He said that design engineering does more to affect cost, quality and flexility than manufacturing ever can.

CINCINNATI MILACRON

Cincinnati Milacron's Manufacturing Systems Division has been a pioneer proponent of flexible manufacturing systems and has done much to popularize the concept.

As a result it has introduced many innovative arrangements of FMS machine tools, tool handling and management systems, and material handling equipment.

Its own FMS installed at its Plastics Machinery Plant in Mt. Orab, located in Brown County near Cincinnati, is designed to produce parts for the 75—350 ton range of injection molding machines produced by this division. Many of the parts are typical hydraulic components.

For this installation, Milacron chose to use four Cincinnati Milacron T30 horizontal machining centers featuring dual pallet workpiece interchange, a horizontal-type coordinate measuring machine, four load/unload stations, a wash station with automatic handling unit, an automatic work changer for in-process queue of work, and an Eaton Kenway XKL Robocarrier automatic wire-guided vehicle system with three computer-controlled carts. These new machining centers can operate as stand-alone or in multi-machine cells.

A PDP 11/44 computer directs the system from a system control center that is in an area elevated above the shop floor.

The flexible manufacturing system is located in a 90 x 250 ft structure that was built between two separate existing buildings. Provision has been made for an automatic storage and retrieval system.

Part parameters of the system include a maximum 32 in. cube part envelope and weighing up to 5,000 lbs. Milacron identified over 200 parts that could fit this envelope and predicted that as many as 3,500 parts would eventually prove suitable for machining on this FMS.

The automatic workchanger shown in the foreground of the illustration holds ten pallets that contain an interesting variety of workpieces as well as variety of fixturing on the pallets. The pallets are transported to the machine tools by means of an AGV cart

Much of the versatility of the FMS is attributed to the software developed by Milacron to drive the system. Fitted with many sensing capabilities, the FMS can operate either lightly manned or unmanned in multiple shifts. Comprehensive analytical software modules are used to simulate scheduling, traffic, tool allocation, and actual production processing.

Four Milacron tool interchange stations, one per machine, are used for transferring the tools that have been delivered by the AGV carts into the chain-type tool storage matrix. At the same time, worn or no-longer needed tools are removed to be taken to the tool load/unload station.

Tool delivery chains are queued at three stations. They are sent to one of four tool interchange stations located one at each machining center.

At the far end of the room shown in the illustration is the pallet/fixture build station.

A flume-type chip/coolant collection and recovery system that was supplied by Henry Filters, Inc., Bowling Green, Ohio, is located beneath the four machining centers and the parts wash station. The installation is located outside of the main machining production area.

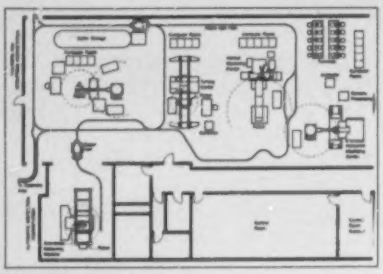
The FMS shown was initially scheduled for startup in the second quarter of 1985. It was hoped that this FMS would cut Milacron's workpiece queue time from days to a matter of hours. Some of the workpieces took as many as 20 days, so this can lead to a significant savings.

Future expansion plans are already well along, including more machines and an automatic storage and retrieval system (AS/RS). Sufficient computing power and software modules have been provided to handle these addtions.

The AS/RS will provide for in-process material and part storage for the FMS and the plastics manufacturing group located in the two existing buildings and the new addition. This combination will give them the flexibility needed to respond to current and anticipated production needs.

The circular automatic workchanger shown above in the foreground holds ten pallets that contain an interesting variety of workpieces as well as fixturing techniques. The pallets are transported to the machine tools by means of an AGV cart

NAT'L BUREAU OF STANDARDS



The AMRF contains horizontal and vertical milling machines, a lathe, automated material-handling equipment, a cleaning and deburring workstation, a coordinate measurement machine and a variety of industrial robots.

The most advanced flexible manufacturing system will, most likely, never see the inside of a factory. The system, called the Automated Manufacturing Research Facility (AMRF), is under development at the Nation Bureau of Standards (NBS) Center for Manufacturing Engineering in Gaithersburg, Md.

AMRF is a proving ground for advanced manufacturing technology. As an open Federal laboratory with no commercial ambitions, the facility is accessible to firms, government agencies, and universities interested in automation research.

It incorporates a wide variety of commercially available machine tools and robots for the purpose of exploring the most practical incremental route to automation for the smaller firm.

Research at Gaithersburg covers everything from the preparation of data on a new part to final automated inspection. As to be expected from a facility run by the NBS, the development of new manufacturing standards as well as new methods of measurement and quality control for automated factories is a major aim of the research.

The program has two principle goals: to supply American industry with a new ways to make precise measurements of machined parts, and to encourage industrial modernization by providing the technical information necessary for the development of standardized interfaces between various types of equipment.

Historically, manufacturing and measurement have been separate tasks. A machinist would cut a part, then stop periodically to check its dimension with calipers and gauges.

The aim at Gaithersburg is to do both operations at the same time. If the two processes could be done simultaneously, if machining a part also meant measuring it, products would not only be produced in less time but more accurately.

Another goal is to bring automated manufacturing systems within the reach of smaller firms, firms that cannot afford to buy a ready-made FMS from a single supplier or hire the experts needed to work out the complex interfaces between otherwise incompatible equipment. Smaller firms need to be able to build up their FMS incrementally, inexpensively integrate different machines from different venders, and switch quickly from the production of one part to another without expensive reprogramming.

Standardization—standard procedures, standard protocols, standard interfaces—will help firms develop these capabilities. And standards is the name of the game for the NBS and AMRF.

The AMRF contains horizontal and vertical milling machines, a lathe, automated material-handling equipment, a cleaning and deburring workstation, a coordinate measurement machine and a variety of industrial robots.

It also has a number of special features like modular hierarchical software. The actions of the machines in the facility are based on information in a database system which holds the design of the part being produced. A change in the database is all that is required to change the part being produced.

Another feature is the real-time system controller. It uses information fed back to it from a variety of sensors to modify its control decisions, allowing a robot or machine tool to react to variations in the environment. An advanced vision system is also featured. A robot projects bars of light across its field of view; the vision computer, then, observes how images of bars of light bend as they fall across objects and uses that information to deduce the position and shape of the objects. The vision system does not have to be taught what to see but gets descriptive information from the database. Eventually the information will be culled simply from a CAD part description.

The master program that governs the computer controller for one workstation is based on Lisp, an artificial intelligence language.

MURATA WARNER SWASEY

Onan's automated system includes two lines. One line contains a punch press while the other employs a punch press, shear and sorter. Parts from both lines are moved by wire-guided vehicle to press brake equipment.

Flexible manufacturing is not just for machining prismatic or rotational parts, although these areas have received the lion's share of attention. Increasingly, firms that produce parts made of sheet metal are turning to flexible systems.

The Wiedemann Div. of Warner & Swasey, a Cross & Trecker Company, King of Prussia, Pa., has sold some 60 flexible fabrication systems (FFS) and cells. One of the most sophisticated of these systems was delivered in 1983 to an affiliate company, Murata Warner Swasey Company, Ltd., Inuyama City, Japan. Murata, among other things, builds turning machines and CNC punch presses.

The Japanese system is significant in that it employs a variety of material handling devices that keep punching, shearing, and forming machines supplied with just-in-time deliveries.

"The material handling technology ranges from an automated storage and retrieval system to dedicated traversing tables, a sort system, and general purpose wire-guided vehicles," said Brad Peck, marketing manager, Wiedemann Div.

The automated system includes two lines. One line contains a punch press while the other employs a punch press, shear and sorter. Parts from both lines are moved by wire-guided vehicle to press brake equipment.

One reason Murata decided on the Wiedemann FFS was its parts nesting ability. Nesting permits a manufacturer to optimally lay out or nest a variety of parts on a single sheet of material. "In justifying this type of system, the first thing we are talking about is being able to randomly nest a day's production requirements; then punch and shear those requirements in a process mode rather than an individual parts mode," said Mr. Peck.

"The first economic advantage of nesting is that we optimize material utilization," continued Mr. Peck. "We reduce scrap and save on material costs. Secondly, since a variety of parts are being punched out on one large sheet, we dramatically reduce punch press time. We have a lot less material handling and a lot less tool change time because we are able to optimize tool selection."

ONAN CORP.: What is believed to be the most comprehensive sheet metal fabrication FMS in the U.S. is located at Onan Corp.'s plant in Minneapolis.

The Onan FMS is also the most complex system delivered by Trumpf America in that everything is handled automatically. The system includes an automated storage and retrieval system, automatic parts loading and unloading, a high-speed Trumatic 180 Laserpress CNC precision punching and laser cutting machine, robotic tool changer, tool storage for 300 tools in three tool towers, automatic sorting arrangement and automatic storage.

The entire FMS consists of many integrated subsystems. The storage and retrieval subsystem has a rack having 51 material bins, each capable of holding 6,600 lbs. of sheet or plate material up to $^1/_4$-in. thick. A guided transfer cart delivers pallets of raw material that have been pre-loaded by the steel suppliers to an automatic sheet loader. A thickness device and double-thickness device ensure single-sheet transfer of the proper gage of material.

Finished parts up to 8 x 16 in. are fed into a programmable drop chute located adjacent to the laser cutting head. A linear shuttle device with six part bins sort out six part-size categories. Parts larger than 8 x 16 in. are picked up by an unloading device that has 72 suction cups that can be individually programmed to conform to desired hole patterns and sheet size.

At Onan, a Digital Equipment VAX-750 manages the system, including inventory control of tooling in the towers and material in the storage and retrieval system, incoming order information, an interface with CAD/CAM design of the piece parts.

DAIMLER-BENZ

The system installed by Hüller Hille at a Daimler-Benz plant in Germany to make a variety of exhaust manifolds is not an FMS but a flexible transfer line. The system does not use off-the-shelf equipment nor flexible spindles like those found on machining centers, the heart of most FMSs. However, the system does offer flexibility.

At Daimler-Benz, the Hüller Hille line turns out 200 varieties of manifolds, a flexibility that is achieved by moving the fixturing rather than the machine tool spindle. Flexible lines are more popular in Europe than in the U.S., especially among European auto makers, which use them to service relatively small, diverse markets.

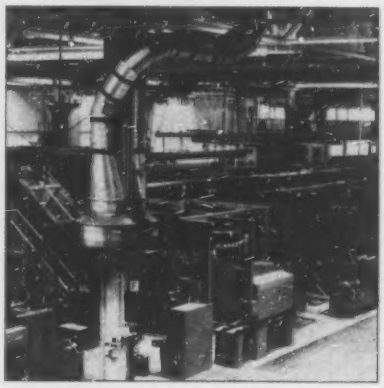
Flexible transfer lines are composed of custom machines, machines designed to give a firm just the flexibility it needs. FMS, it is argued, often gives companies more flexibility and therefore greater costs then needed. Also, while a flexible line is built to optimally satisfy a unique set of production needs, an FMS, composed of standard tools, is no optimal solution.

Some features of the line include an overhead transfer conveyor for moving the workpieces, and five positioners which each present workpieces to clamping fixtures correctly positioned in five axes. These positioning fixtures give the line much of its flexibility.

Operations begin with the overhead transfer system placing the workpieces in the clamping fixtures of an indexing machine which aligns the manifolds. The line has three machining stations which mill the faces of the cylinder head flanges, drill the fixing holes, and counterbore inlet passages.

At the end of the line, the manifolds are transferred to another indexing machine. Here, the cylinder head flanges are deburred, the workpiece washed and inlet passages inspected.

Place Machine, Troy, Mich., represents Hüller Hille in the U.S.



At Daimler-Benz, the Hüller Hille line turns out 200 varieties of manifolds. However, that flexibility is achieved by moving the fixturing rather than the machine tool spindle.

CITROEN:

"A return on investment is not the main factor in FMS. The objectives are to produce goods, reduce operating costs, and to make money," said Michael Parent, research director of Société Automatique Industrielle (SAI), Paris. He spoke of FMS knowingly since his firm planned and built an FMS for Citroën Mecanique (CCM) at Meudon, France.

This 500 mm-cube working envelope flexible manufacturing system machines a wide range of components, from differential housings to cylinder heads, in average batch sizes of 50. Materials used include light alloys, cast irons and steels.

The FMS is capable of five-axis machining. It is organized around three five-axis Graffenstaden-built machining centers that are supplied with components and tools by five automatic guided vehicles (AVGs). The AGVs transport tools from a 600-tool capacity store, which is updated by new or redressed and set tools from a Italian-built computerized tool measuring and setting station.

Castings and fabricated parts are loaded/unloaded at six stations. AGVs then move the palletized workpieces to the machining center area. After machining, the components go to a surface treatment robot station and a washing machine. The system contains a 54-pallet store and seven automatic pallet load/unload stations.

A tri-level, hierarchial computerized control manages the FMS. At the top level is a CAD/CAM system provided by Computervision-Europe. This system generates production data and CNC programs. At the second level is a centralized control based on two minicomputers (one is a back-up unit) with peripherals and graphic display of visual FMS status.

At the third level are the distributed FMS controls. These include the three CNC machining centers, the robot, the coordinate measuring machine, the tool magazine, tool measuring and setting machine, pallet magazine control, the AGV system, and three on-floor terminals at the manual load/unload stations.

WHITE SUNDSTRAND

The most recent announcement of a purchase of a flexible manufacturing system apparently comes from Lockheed-Georgia Co., Marietta, Ga. The aircraft manufacturer selected the WCI Machine Tools & Systems Division of White Consolidated Industries, Cincinnati, as the contractor to install this new system. The announcement is another ripple in the flood of FMS orders from aerospace firms in recent months.

"The driver there is the Department of Defense. They have come up with the IMIP (Industrial Modernization Incentive Programs)," said an aerospace company official. "And to be a candidate for the program is the real incentive we needed to go out and purchase an FMS, because now we can get a good solid return on our investment and in past that was lacking."

Some of the aerospace firms that have recently installed or ordered FMSs include: Vought Corp., General Dynamics Corp., Boeing Co., McDonnell Douglas Corp., and Hughes Aircraft Co.

The Lockheed-Georgia system will cost between $11 to 12 million and will be operating by December 1986. It will be able to automatically store, transport, machine, clean, and inspect a group of some 140 precision parts up to 60 in. long.

The system will employ five 5-axis machining centers, each accessing a minimum of 90 cutting tools. Additionally, the FMS will have an automatic storage and retrieval system, a 20-station pallet and part queue, three wire guided vehicles, a wash station, and a coordinate measurement machine to inspect the parts.

During the day shift, the pallet and part queue will be stocked with palletized parts. Then, on the off shifts the parts will be processed. Production lot sizes will range from one to 15 parts per order.

A VAX-11/750 computer in our distributed numerical control system will provide production work order data to the FMS computer," said Ronald G. Bergeron, FMS project manager. "These will include part numbers, lot sizes, start and finish dates, operating sequences, raw material data, fixturing data, and NC tape numbers."

LASALLE: The LaSalle Machine Tool Division of Acme-Cleveland Corp., Troy, Mich., with its installation of an advanced FMS at Vickers Inc., has served notice that it has the credentials to serve the FMS marketplace. Vickers, a subsidiary of Libby-Owens-Ford Co., has purchased the system to produce a family of iron and steel cylinder blocks for hydraulic piston pumps that serve a variety of industrial and commercial needs.

The flexible manufacturing system handles from 25 to 30 different block designs. The blocks, ranging from 2 to 60 lbs, reportedly are manufactured at rates of from 35 to 135 blocks per hour, depending on complexity of the parts.

These blocks are being machined by five CNC hole-generating machines from LaSalle, automatic turning and facing machines from Olofsson Corp, Lansing, Mich., and a single ram, dual-positioning vertical broaching machine supplied by American Broach & Machine Co., Ann Arbor, Mich.

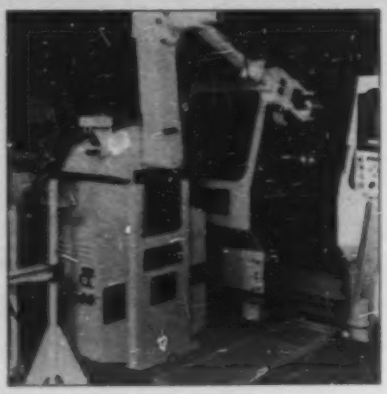
Besides turning, facing, boring, and broaching, the system will perform heat treating, press assembly, gauging and washing.

Other equipment in the system includes 11 robots, machine vision systems, automated gauging machines, and an automatic parts conveyor systems as well as automatic parts handling and loading devices.

Altogether, the system contains 18 work cells and cost about $18 million. The 18 cells will be linked by a network of parallel conveyors. One conveyor system will move parts one at a time through the turning centers while another will move the parts four at a time by pallets through the remaining machining operations.

White Sunstrand uses its OM2-A Omnimil in some of the FMS it designs. Currently the company is engaged in a contract with Lockheed-Georgia. The system will cost between $11 to 12 million and will be operating by December 1986.

OKUMA MACHINERY WORKS



Unlike its 1972 "Parts Center 1," which used many robot-like "hands" to transfer shafts from one operation to another, Okuma's FMS-MC-1 uses a series of machining centers located perpendicular to the material handling line. The line is designed for machining parts in small lot sizes on a 24-hr. basis.

The in-house FMS at Okuma Machinery Works' Oguchi plant in Japan is noteworthy because of the pioneer and innovative work done by the firm in automating machining operations.

Unlike its 1972 "Parts Center 1," which used many robot-like "hands" to transfer shafts from one operation to another, Okuma's FMS-MC-1 uses a series of machining centers located perpendicular to the material handling line. The line is designed for machining parts in small lot sizes on a 24-hr. basis.

Based on reports from Japan, the FMS-MC-1 consists of seven horizontal-spindle machining centers, each of which is controlled by a OSP 5000 CNC built by Okuma. The machining centers are in a row so that each machine can receive and store pallets. Unmanned trackless Robotrailers are used to supply parts to the "pallet pool" stations at the machines. Material to be machined is set on pallets in a handling area and then transferred to each machining center by the Robotrailer. After machining, the finished parts are returned to the handling area by a same Robotrailer.

A centralized tool room maintains an inventory of over 500 preset tools for the Okuma machining centers. The tools are set on pallets and are transported when needed by Robotrailer to the magazine station beside each machine.

At its introduction, nearly 100 parts could be machined on this system. The main production was spindleheads for the firm's lathes and machining centers, tailstocks for grinding machines, and saddles for lathes.

This FMS was the first of about twelve systems planned by Okuma for its factories.

EX-CELL-O CORP.: One of the more interesting new products from Ex-Cell-O Corp. is a FlexCenter horizontal spindle machining center developed jointly by its U.S. and European engineering departments.

According to Ex-Cell-O, the FlexCenter will be the core on which they intend to build flexible manufacturing cells and systems. It is modular in design so that it can be used as a stand-alone machine or as one of several machines that are linked together. The company said that FlexCenters have already been incorporated into flexible transfer lines that the company builds.

The modular design is also in keeping with the admonition of FMS experts to "begin small and keep things simple." Ex-Cell-O's FlexCenter line consists of four models. The smallest, the 220, uses 500 mm sq. pallets. The two intermediate sizes handle pallets 630 and 800 mm sq. respectively, while the largest, the 520, uses pallets that are 1,000 mm sq. These are DIN Standard sizes. The pallets have T-slots for greater flexibility in mounting fixtures and workpieces.

At the heart of the FlexCenter machines is a massive 5,000 rpm spindle that is powered by either a 30- or 40-hp AC drive. Ultra-high-speed spindles of 40,000 rpm are available.

In order to have the right tooling available for the cell's use when needed, a choice of fixed, manually interchanged or automatically interchanged tool storage conveyors is offered. Two multi-spindle head loading systems provide convenient storage and automatic insertion of 16 in. sq. heads. One of these systems is an overhead gantry for ready accessibility to the machines.

Flow-through chip management eliminates problems encountered with chips on conventional machines. A tool shank cleaning system helps eliminate chips and dirt that cause tool seating problems.

Feeds and positioning are aided by the use of a patented zero-backlash contouring table, glass scale positioning systems, 600-ipm traverse speeds, high-response AC servos and self-aligning lead screws.

Options for the FlexCenter include probing, tool sensing, thermal compensation, vision part identification, and diagnostics. The standard control is a GE 2000MC, while optional controls are either Allen-Bradley of General Numeric.

PRICE & PRODUCTION DATA

(Effective July 22,1985)

Steel production by districts, thousands of tons (000 omitted)

	Last Week	Two Weeks Ago	Month Ago	Year Ago
Northeast Coast	149	168	188	218
Pittsburgh	219	210	224	247
Youngstown	91	97	100	88
Lake Erie	119	117	118	120
Detroit	133	137	117	189
Chicago	482	495	455	466
Cincinnati	92	92	90	89
St. Louis	72	75	79	60
Southern	210	210	206	188
Western	92	94	94	79
U.S. Production	1,659	1,695	1,671	1,744

Source: American Iron & Steel Institute

Lake Superior Ore Prices

51.50% Fe Natural delivered lower Lake ports. Rail transportation, handling and unloading may be charged to the account of the buyer. Coarse ore 80¢ premium.

Pellets (per iron unit natural ..... gross-ton 80.50-86.9*
Mesabi, regular-unscreened ..... gross-ton $32.53
Mesabi, non-bessemer ..... gross-ton $30.03-31.53**

*80.50¢—Pickands Mather as of 1/27/81.
86.9¢—U.S. Steel as of 3/15/82. Cleveland-Cliffs as of 2/26/82. Oglebay Norton as of 3/25/82, and Hanna Mining as of 2/26/82.
**Effective 8/1/83.

STEEL PRODUCTION, COMPOSITE PRICES

(Effective July 22,1985)

U.S. Steel Production	Last Week	Two Weeks Ago	To Date 1985	To Date 1984
Net tons, in thousands	1,659	1,695	50,010	55,862
Capability Utilization Rate	65.1	66.5	67.7	74.8

Composite Prices	This Week	Week Ago	Month Ago	Year Ago
Finished Steel Base* (¢/lb.—eff. 7/1/84)	27.582	27.582	27.582	27.582
Pig Iron** (Net ton = 2000 lbs.)	$213.00	$213.00	$213.00	$213.00
Scrap No. 1 hvy.*** (Gross ton = 2240 lbs.)	$ 69.17	$ 68.83	$ 66.17	$ 82.17
No. 2 bundles	$ 51.17	$ 50.50	$ 47.17	$ 50.83

Scrap Comparison (Gross Ton)

No. 1 steel, Pittsburgh	$ 72.50	$ 72.50	$ 70.50	$ 88.50
No. 1 steel, Philadelphia	71.50	70.50	66.50	80.50
No. 1 steel, Chicago	63.50	63.50	61.50	77.50
No. 1 bundles, Detroit	64.50	64.50	59.50	75.50
Low Phos., Youngstown	57.50	57.50	57.50	80.50
No. 1 mach'y cast., Pgh	71.50	71.50	71.50	75.50
No. 1 mach'y cast., Phila	91.50	91.50	91.50	98.50
No. 1 mach'y cast., Chi	99.50	99.50	99.50	115.50

*Finished Steel Composite: Weighted index of steel bars, shapes, plates, wire, rails, black pipe, hot and cold rolled sheets and strips.
**Pig Iron Composite: Based on average prices for basic and foundry pig iron at representative producing points within the U.S.
***Steel Scrap Composite: Average of No. 1 hvy. melting steel scrap and No. 2 bundles delivered to consumers at Pittsburgh, Philadelphia and Chicago.

NONFERROUS PRICES

(Effective July 22,1985) Prices obtained in trade based on representative tonnages per gross ton delivered to consumer unless otherwise stated.

Primary Metal Prices

(cents per lb.)	current price	last price	date of change
Aluminum (LME)	46.42	45.57	7/22/85
Copper (C)	67.00-68.50	66.00-68.00	7/19/85
Lead	19.00-21.00	18.50-21.00	7/18/85
Magnesium Ingot	148.00	143.00	5/25/84
Nickel (LME)	229.88	228.47	7/22/85
Titanium Sponge	555.00-585.00	555.00	4/29/82
Zinc	41.00-47.00	44.00-47.00	7/11/85

ALUMINUM: Avg. for last week & previous week. COPPER (C) = cathode. LEAD: common grade. MAGNESIUM: 99.8% pig, delivered. NICKEL: Avg. for last week & previous week. ZINC: high grade.

Antimony, American Laredo, Texas	$2.00
Beryllium-aluminum 5% Be, per lb. contained Be	$230.00
Beryllium-copper, per lb. cont. Be	$144.00
Beryllium 97% powder 200	$178.00
Cadmium, ton lots	$1.25-1.55
Calcium, ton lots, crown	$3.76
Chromium, 99.8%	$3.75
Cobalt, 99%, cathode	$12.50
Gold per troy oz.	$317.25
Indium, dollars per troy oz.	$2.50
Iridium, dollars per troy oz.	$410.00
Magnesium sticks, 10,000 lbs.	$2.02
Mercury, per 76-lb. f.o.b. N.Y.	$310.00-323.00
Molybdenum, lb. tech. moly oxides, 20 lb. MO can	$6.85
Nickel electro (PDCR)	$3.29
Palladium, per troy oz.	$96.00
Platinum, per troy oz.	$276.00
Rhodium, per troy oz.	$675.00
Silver ingots, per troy oz.	$6.08
Vanadium	$6.00
Zirconium sponge	$12.00-17.00

(Per lb. unless otherwise noted)

Straits Tin Price

(U.S. cents per lb. EX-SMELTER, based on daily market in Penang in Malaysian dollars per kilo.)

July 15—564.17
July 16—564.17
July 17—568.11
July 18—564.76
July 19—568.22

Scrap Prices
Brass Mill Scrap

(Cents per lb.; over 20,000 lbs. add 1¢ per lb)

	Solids	Turnings
Copper	60	47
Yellow brass	53¾	46¾
Red brass	56½	45¼
Comm. bronze	57¾	45½
Mang. bronze	45¾	44¾
Free cutting rod ends	47	46

Custom Smelters Scrap

(Cents per lb., carload lots, del. refinery)

No. 1 copper wire	56
No. 2 copper wire	48
Light copper	40

Ingot Makers Scrap

(Cents per lb., carload lots, del. refinery)

No. 1 copper wire	52
No. 2 copper wire	44
Light copper	36
No. 1 composition	46
No. 1 comp. turnings	44
Hvy. yellow brass solids	33
Hvy. yellow brass turnings	30
Radiators	35

Aluminum

New mixed clips	30	— 32
Old sheet	28	— 29
Old cast	28	— 29
Clean dry borings	29	— 30

Dealers' Scrap

(Dealers' buying price f.o.b. New York in cents per pound)

Aluminum

Segregated clippings	25	— 26
Mixed I.C. clips	23	— 24
Old sheets and cast	20	— 22
Borings and turnings	17	— 18
Duraluminum clippings	24	— 25

Copper and Brass

No. 1 copper wire	45	— 46
No. 2 copper wire	37	— 38
Light copper	32	— 33
Radiators	30	— 31
No. 1 composition	38	— 40
No. 1 composition turnings	35	— 37
Cocks and faucets	27	— 29
Clean heavy yellow brass	26	— 28
Brass Pipe	27	— 29
New soft brass clippings	39	— 40

Lead

Heavy soft lead	6	— 8
Whole batteries	1	— 3
Type metal	16	— 17
Electrotype	13	— 15

Nickel

Nickel solids	120	—130
Nickel rod ends	120	—130
Nickel sheets, clips	120	—130
Nickel turnings	35	— 45

Zinc

New zinc clippings	17	— 18
Old diecast zinc	13	— 14

EFFECTIVE JULY 22, 1985

(Effective July 22, 1985) Prices obtained in trade based on representative tonnages per gross ton delivered to consumer unless otherwise stated. Prices are the opinions of Iron Age editors and correspondents, based on contacts with dealers, brokers, germinators and users in the industry on the effective date listed above.

Ferrous Scrap Prices

Pittsburgh

No. 1 hvy. melting	$ 72.00 to	$ 73.00
No. 2 hvy. melting	62.00 to	63.00
No. 1 dealer bundles	82.00 to	83.00
No. 1 factory bundles (auto)	78.00 to	79.00
No. 2 bundles	54.00 to	55.00
No. 1 busheling	80.00 to	81.00
Machine shop turnings	7.00 to	8.00
Shoveling turnings	40.00 to	41.00
Cast iron borings	38.00 to	39.00
Low phos. punchings plate	84.00 to	85.00
Heavy turnings	62.00 to	63.00
No. 1 RR hvy. melting	83.00 to	84.00
Rails, 2 ft. and under	96.00 to	97.00
Scrap rails, random lgth	81.00 to	82.00
RR specialties	90.00 to	91.00
No. 1 machinery cast	71.00 to	72.00
Cupola cast	64.00 to	65.00
Heavy breakable cast	30.00 to	31.00
Stainless		
18-8 bundles and solids	615.00 to	625.00
18-8 turnings	515.00 to	525.00

Chicago

No. 1 hvy. melting	$ 63.00 to	$ 64.00
No. 2 hvy. melting	59.00 to	60.00
No. 1 dealer bundles	84.00 to	85.00
No. 1 factory bundles (auto)	76.00 to	77.00
No. 2 dealer bundles	53.00 to	54.00
No. 1 busheling	80.00 to	81.00
Shredder scrap	77.00 to	78.00
Machine shop turnings	40.00 to	41.00
Mixed borings and turnings	41.00 to	42.00
Shoveling turnings	43.00 to	44.00
Cast iron borings	39.00 to	40.00
Low phos. forge crop	94.00 to	95.00
Low phos. punchings plate 1/4 in. and heavier	109.00 to	110.00
Low phos. 2 ft. and under	104.00 to	105.00
No. 1 RR hvy. melting	74.00 to	75.00
Scrap rails random lgth	72.00 to	73.00
Reroller rails	95.00 to	96.00
Rails, 2 ft. and under	97.00 to	98.00
RR couplers and knuckles	86.00 to	87.00
RR car axles	104.00 to	105.00
No. 1 machinery cast	99.00 to	100.00
Cupola cast	87.00 to	88.00
Stove plate	87.00 to	88.00
Steel car wheels	84.00 to	85.00
Stainless		
18-8 bundles and solids	555.00 to	565.00
18-8 turnings	465.00 to	475.00
430 bundles and solids	145.00 to	150.00
430 turnings	115.00 to	120.00

Philadelphia

No. 1 hvy. melting	$ 70.00 to	$ 73.00
No. 2 hvy. melting	60.00 to	63.00
No. 1 dealer bundles	83.00 to	86.00
No. 2 dealer bundles	44.00 to	47.00
No. 1 busheling	83.00 to	86.00
Shredder scrap	83.00 to	86.00
Machine shop turnings	25.00 to	28.00
Mixed borings and turnings	25.00 to	28.00
Shoveling turnings	39.00 to	42.00
Low phos. 5 ft. and under	80.00 to	83.00
Low phos. 2 ft. punchings	97.00 to	100.00
Electric furnace bundles	82.00 to	85.00
RR specialties	80.00 to	83.00
Rails, 2 ft. and under	98.00 to	101.00
Cupola cast	76.00 to	79.00
Heavy breakable cast	53.00 to	56.00
No. 1 machinery cast	90.00 to	93.00

Detroit

Brokers buying prices per gross ton on cars:

No. 1 hvy. melting	$ 50.00 to	$ 51.00
No. 2 hvy. melting	49.00 to	50.00
No. 1 dealer bundles	64.00 to	65.00
No. 2 bundles	28.00 to	29.00
No. 1 busheling	63.00 to	64.00
Drop forge flashings	40.00 to	41.00
Machine shop turnings	36.00 to	37.00
Mixed borings and turnings	16.00 to	17.00
Shoveling turnings	36.00 to	37.00
Cast iron borings	23.00 to	24.00
Heavy breakable cast	33.00 to	34.00
Mixed cupola cast	48.00 to	49.00
Automobile cast	72.00 to	73.00
Stainless		
18-8 bundles and solids	525.00 to	535.00
18-8 turnings	415.00 to	425.00
430 bundles and solids	115.00 to	125.00

Youngstown

No. 1 hvy. melting	$ 50.00 to	$ 53.00
No. 2 hvy. melting	39.00 to	42.00
No. 1 dealer bundles	66.00 to	69.00
No. 2 dealer bundles	29.00 to	32.00
Machine shop turnings	8.00 to	11.00
Shoveling turnings	13.00 to	16.00
Low phos. plate	56.00 to	59.00
Electric furnace bundles	53.00 to	56.00
Galvanized bundles	46.00 to	49.00

Cleveland

No. 1 hvy. melting	$ 50.00 to	$ 53.00
No. 2 hvy. melting	30.00 to	33.00
No. 1 dealer bundles	64.00 to	67.00
No. 1 factory bundles	55.00 to	58.00
No. 2 bundles	25.00 to	28.00
No. 1 busheling	64.00 to	67.00
Machine shop turnings	10.00 to	13.00
Mixed borings and turnings	8.00 to	11.00
Shoveling turnings	18.00 to	21.00
Cast iron borings	15.00 to	18.00
Cut structural & plates, 2 ft. and under	92.00 to	95.00
Low phos. punchings plate	92.00 to	95.00
Drop forge flashings	43.00 to	46.00
Foundry steel, 2 ft. & under	66.00 to	69.00
No. 1 RR hvy. melting	56.00 to	59.00
Rails, 2 ft. and under	83.00 to	86.00
Rails, 18 in. and under	87.00 to	90.00
Steel axle turnings	56.00 to	59.00
Railroad cast	87.00 to	90.00
No. 1 machinery cast	85.00 to	88.00
Cupola cast	55.00 to	58.00
Stove plate	51.00 to	54.00
Stainless		
18-8 bundles	375.00 to	385.00
18-8 turnings	325.00 to	335.00
430 bundles	80.00 to	85.00

Buffalo

Brokers buying prices per gross ton on cars:

No. 1 hvy. melting	$ 51.00 to	$ 52.00
No. 2 hvy. melting	41.00 to	42.00
No. 1 busheling	65.00 to	66.00
No. 1 dealer bundles	65.00 to	66.00
No. 2 bundles	31.00 to	32.00
Machine shop turnings	15.00 to	16.00
Mixed boring and turnings	15.00 to	16.00
Shoveling turnings	21.00 to	22.00
Cast iron borings	23.00 to	24.00
Low phos. plate	77.00 to	78.00
Structural and plate, 2 ft. and under	79.00 to	80.00
Rails, 2 ft. and under	79.00 to	80.00
Scrap rails, random lgth	65.00 to	66.00
No. 1 machinery cast	76.00 to	77.00
No. 1 cupola cast	58.00 to	59.00

St. Louis

No. 1 hvy. melting	$ 45.00 to	$ 46.00
No. 2 hvy. melting	34.00 to	35.00
Foundry steel, 2 ft.	43.00 to	44.00
No. 1 dealer bundles	45.00 to	46.00
No. 2 bundles	29.00 to	30.00
Machine shop turnings	14.00 to	15.00
Shoveling turnings	20.00 to	21.00
Cast iron borings	28.00 to	29.00
No. 1 RR hvy. melting	48.00 to	49.00
Rails, random length	52.00 to	53.00
Rails, 18 in. and under	65.00 to	66.00
RR specialties	65.00 to	66.00
Cupola cast	71.00 to	72.00
Heavy breakable cast	49.00 to	50.00
Stove plate	86.00 to	87.00
Steel car wheels	75.00 to	76.00
Rerolling rails	64.00 to	65.00
Unstripped motor blocks	58.00 to	59.00

Birmingham

No. 1 hvy. melting	$ 71.00 to	$ 72.00
No. 2 hvy. melting	68.00 to	69.00
No. 1 dealer bundles	72.00 to	73.00
No. 2 bundles	46.00 to	47.00
No. 1 busheling	72.00 to	73.00
Shredder scrap	86.00 to	87.00
Machine shop turnings	25.00 to	26.00
Shoveling turnings	37.00 to	38.00
Cast iron borings	35.00 to	36.00
Electric furnace bundles	66.00 to	67.00
Elec. furnace, 3 ft. & under	66.00 to	67.00
Structural and plate, 2 ft.	85.00 to	86.00
Structural and plate, 4 ft.	82.00 to	83.00
No. 1 RR hvy. melting	82.00 to	83.00
Scrap rails, random lgth	77.00 to	78.00
Rails, 2 ft. and under	91.00 to	92.00
Angles and splice bars	83.00 to	84.00
No. 1 cupola cast	82.00 to	83.00
Unstripped motor blocks	75.00 to	76.00

Cincinnati

Brokers buying prices per gross ton on cars:

No. 1 hvy. melting	$ 43.00 to	$ 44.00
No. 2 hvy. melting	42.00 to	43.00
No. 1 dealer bundles	48.00 to	49.00
No. 2 bundles	23.00 to	24.00
Machine shop turnings	3.00 to	4.00
Shoveling turnings	5.00 to	6.00
Cast iron borings	12.00 to	13.00
Low phos. 18 in. and under	76.00 to	77.00
Rails, random length	54.00 to	55.00
Rails, 2 ft. and under	68.00 to	69.00
No. 1 cupola cast	55.00 to	56.00
Heavy breakable cast	21.00 to	22.00
Drop broken cast	68.00 to	69.00

New York

Brokers buying prices per gross ton on cars:

No. 1 hvy. melting	$ 44.00 to	$ 45.00
No. 2 hvy. melting	35.00 to	36.00
No. 2 dealer bundles	20.00 to	24.00
Mixed borings and turnings	10.00 to	11.00
Machine shop turnings	4.00 to	6.00
Shoveling turnings	10.00 to	12.00
Clean cast, chem. borings	35.00 to	36.00
No. 1 machinery cast	79.00 to	80.00
Mixed yard cast	50.00 to	51.00
Heavy breakable cast	10.00 to	12.00
Stainless		
18-8 prepared solids	520.00 to	540.00
18-8 turnings	420.00 to	440.00
430 prepared solids	90.00 to	110.00
410 solids	80.00 to	90.00

Boston

Brokers buying prices per gross ton on cars:

No. 1 hvy. melting	$ 49.00 to	$ 51.00
No. 2 hvy. melting	39.00 to	41.00
No. 1 dealer bundles	51.00 to	53.00
No. 2 bundles	32.00 to	34.00
No. 1 busheling	57.00 to	59.00
Shredder scrap	59.00 to	61.00
Machine shop turnings	10.00 to	12.00
Shoveling turnings	18.00 to	20.00
No. 1 machinery cast	75.00 to	80.00
Mixed cupola cast	42.00 to	44.00
Heavy breakable cast	8.00 to	10.00

San Francisco

No. 1 hvy. melting	$ 38.00 to	$ 40.00
No. 2 hvy. melting	32.00 to	34.00
No. 1 dealer bundles	29.00 to	31.00
No. 2 dealer bundles	17.00 to	19.00
Machine shop turnings	5.00 to	9.00
Cast iron borings	8.00 to	9.00
No. 1 cupola cast	80.00 to	82.00

Los Angeles

No. 1 hvy. melting	$ 38.00 to	$ 40.00
No. 2 hvy. melting	32.00 to	34.00
No. 1 dealer bundles	29.00 to	31.00
No. 2 dealer bundles	16.00 to	18.00
Machine shop turnings	13.00 to	14.00
Shoveling turnings	10.00 to	11.00
Cast iron borings	8.00 to	9.00
Elec. furnace, 1 ft. and under (foundry)	70.00 to	72.00
No. 1 cupola cast	72.00 to	74.00

Seattle

No. 1 hvy. melting	60.00 to	62.00
No. 2 hvy. melting	51.00 to	53.00
No. 2 bundles	35.00 to	37.00
No. 1 cupola cast	89.00 to	90.00
Mixed yard cast	80.00 to	82.00

Hamilton, Ont.

Brokers buying prices per gross ton on cars:

No. 1 hvy. melting	$ 71.00
No. 2 hvy. melting, cut 2 ft. and under	63.00
No. 1 dealer bundles	69.00
No. 2 bundles	47.00
Mixed steel scrap	45.00
Bush. new fact. prep'd	71.00
Bush. new fact. unprp'd	60.00
Machine shop turnings	31.00
Short steel turnings	31.00
Mixed borings and turnings	18.00
Cast scrap	87.00

Houston

Brokers buying prices per gross ton on cars:

No. 1 hvy. melting	$ 67.00 to	$ 68.00
No. 2 hvy. melting	54.00 to	55.00
No. 2 bundles	40.00 to	41.00
Machine shop turnings	13.00 to	14.00
Crushed turnings	30.00 to	31.00
Shredder scrap	76.00 to	77.00
Cut structural plate, 2 ft. and under	96.00 to	97.00
Cut structural plate, 5 ft. and under	80.00 to	81.00
Unstripped motor blocks	60.00 to	61.00
Cupola cast	84.00 to	85.00

IT IS STILL ALL QUIET ON THE PRICE FRONT

Most price-watching these days is bent on detecting early signs of any breakthroughs along a long-quiet front. It has called for patience.

Some jittery watchers feel that they saw, in June, ominous signs on the price front. They acknowledged that the Labor Dept.'s Producer Price Index didn't budge at all in June. However, they pointed out that the flat-price showing was due almost entirely to price declines for energy goods and foods. Energy, especially, showed price softness. The energy goods price index declined by 2.0 pct from May.

So, say these price watchers, the zero price change officially noted for finished goods prices in June, is deceptive. They jump on one statement made by the Labor Dept.: "Finished goods others than foods and energy climbed at a 4.1 pct annual rate in June, considerably more than in comparable recent periods."

However, more cool-headed price watchers pointed out that energy prices fell in June as an expected reaction to sharp increases in both April and May. They see a 'leveling out' process at work in the June energy price rise.

Too much can be read into month-by-month data. A longer-term look at prices, right through June, shows that prices have had some roll to them, but that's all.

During the first six months of this year, the Finished Goods Price Index increased at a seasonally adjusted annual rate of 1.4 pct. That compares to rise rates of 0.6 pct in the second half of 1984 and 2.8 pct in the six months before that.

The metalworking price trend table here shows no surprises for June. The sharp price rise for heavy trucks was expected. Demand for these trucks has run high and, at the same time, tags on trucks had not been adjusted in a long time.

Latest Month Covered: June 1985

Products	Index Reading For Month (1967 = 100)	Pct Change From Previous Month	Pct Change From Year Ago Month
Metal Cutting Machine Tools	396.9	+ 0.1	+ 3.4
Metal Forming Machine Tools	433.8	+ 0.3	+ 2.4
Agricultural Machinery & Equip.	339.5	+ 0.1	+ 0.5
Construction Machinery & Equip.	362.0	— 0.1	+ 1.1
Industrial Process Furnace & Ovens	384.7	+ 0.1	+ 2.8
Industrial Material Handling Equip.	294.9	+ 0.1	+ 2.1
Pumps, Compressors & Allied Equip.	356.1	+ 0.2	+ 1.8
Fluid Power Equip. (Dec. 1970 = 100)	263.6	— 0.1	+ 1.7
Mechanical Power Transmission Equip.	339.7	+ 0.5	+ 4.9
Automobiles	229.1	+ 0.4	+ 3.8
Motor Trucks—Light	293.3	— 0.7	+ 3.8
Motor Trucks—Heavy	333.3	+ 5.4	+ 0.7
Railroad Equipment	362.6	0	+ 2.3
Fabricated Metal Structural Products	314.8	0	+ 1.2
Electric Motors	352.0	0	+ 3.5
Valves & Fittings (Dec. 1982 = 100)	104.9	+ 0.3	+ 2.8
Ball & Roller Bearings	353.7	+ 1.9	+ 4.0
Cutting Tools & Accessories	285.9	0	+ 2.8
Heating Equipment	259.6	+ 0.5	+ 2.7
Plumbing Fixtures & Brass Fittings	313.1	+ 0.1	+ 3.5
Metal Containers	358.2	0	+ 2.9
Miscellaneous Metal Products	302.5	+ 0.2	+ 2.8

Data based on U.S. Labor Dept.'s Producer Price Index